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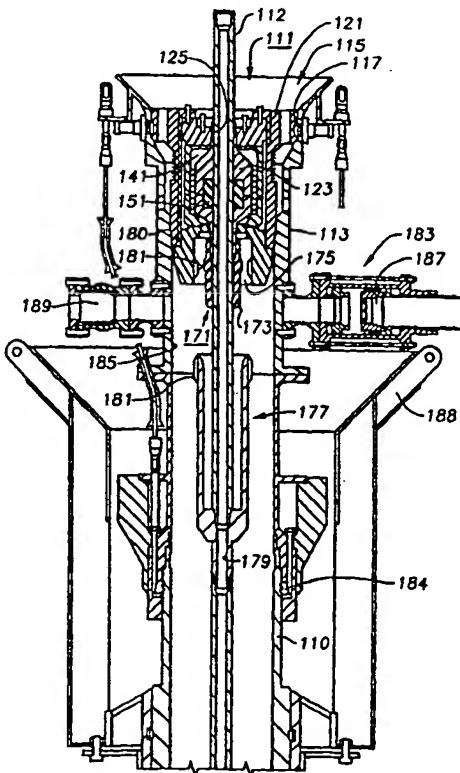
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(54) Title: SUBSEA DIVERTER AND ROTATING DRILLING HEAD

## (57) Abstract

A shallow water flow diverter system of the subsea diverter (113) and rotating drilling head (111) of the invention provides a controlled lube system for mud, cuttings and cement that are produced during the installation of subsea wellhead conductors. The system of the invention has provisions to contain and minimize any shallow water flows that may be encountered and provides the ability to shut off any undesired aquifer flows. Additionally, the system provides the capability to minimize any flows that have been the cause of instability in unconsolidated formations. The diverter housing assembly (113) consists of an upper housing that is flanged to a lower latch assembly (184). An alignment funnel has been incorporated into the top of the diverter housing assembly (113) to guide the shallow water flow diverter insert (111) during installation. In addition, the diverter housing assembly (113) incorporates a choke (187) to channel drilling cuttings and a relief valve (189) that is designed to vent should an overpressure condition occur within the diverter housing assembly. The diverter rotating head insert (111) lands and locks into the diverter housing assembly (113) to provide a dynamic seal on the drill pipe at 140 rpm during drilling operations. The sealing system incorporates two dynamic seals, a stripper rubber seal (171) and the gripper seal (151). The gripper seal is a hydraulically energized rotary seal that forms the secondary sealing barrier on the drill pipe. Hydraulic pressure from the diverter control system compresses the gripper seal assembly around the drill pipe. As the drill pipe turns, the gripper seal will rotate along with the drill pipe. The diverter rotating head insert is run along with the drill pipe using a running tool (177).



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1

## SUBSEA DIVERTER AND ROTATING DRILLING HEAD

2

### Cross-Reference to Related Applications

3

This application claims the benefit of provisional application, United States Serial No.60/080,863, filed 04/06/98.

5

### Technical Field

6

This invention relates in general to rotating drilling heads and in particular to a subsea rotating drilling head that seals against drill pipe during drilling.

8

### Background of the Invention

9

In a subsea well of the type concerned herein, a wellhead housing locates on the sea floor. Strings of casing extend into the well, with the casings being supported in the wellhead housing. A casing hanger seal is installed between the casing hanger at the upper end of the casing and the wall of the wellhead housing. The operator installs the casing and the seal remotely and sometimes in seas of considerable depths.

1           There have been a number of types of running tools used and proposed in  
2           the patented art. With the advent of metal-to-metal casing hanger seals, the forces  
3           required to set these seals are greater than the prior art elastomeric seals. Running  
4           tools have to be capable of delivering very large forces. One type utilizes  
5           hydraulic pressure, as shown in U.S. Patent Nos. 4,969,516 and 4,928,769. The  
6           hydraulic pressure is generated by axial movement of the drill string, which moves  
7           a piston within a sealed hydraulic chamber in the running tool. These hydraulic  
8           tools work well. However, they are complex and expensive.

9           U.S. Patent No. 5,044,442 shows a type that is hydraulically actuated, but  
10          uses annulus pressure. Rams are closed around the drill string, creating a chamber  
11          located above the wellhead housing within the riser. A bulk seal seals a portion  
12          of the running tool to the wellhead housing above the setting sleeve and casing  
13          hanger seal. The bulk seal enables pressure to be applied to a piston of the  
14          running tool. Fluid is pumped down a choke and kill line to this chamber, which  
15          actuates the piston within the running tool to set the casing hanger seal. The  
16          annulus pressure actuated hydraulic tool described in that patent is feasible,  
17          however a possibility exists that the bulk seal could seal on the wellhead housing  
18          at a point above the desired position. If so, the casing hanger seal might be  
19          actuated before it is located fully within the pocket between the casing hanger and  
20          the bore of the wellhead housing.

1                   Subsea drilling is a problem in certain areas, such as the Gulf of Mexico.  
2                   Shallow formations in the Gulf of Mexico present special problems that must be  
3                   solved with a variety of techniques, which include using extra casing strings, etc.  
4                   Another solution proposed is drilling with positive pressure. This may require the  
5                   use of a rotating drilling head, seals and drill pipe. The prior art only used this  
6                   equipment for horizontal or underbalanced wells at the surface, not subsea.

7                   Summary of the Invention

8                   An improved system to provide control of mud, aquifer and cement flows  
9                   experienced during installation of subsea conductor strings is provided. The  
10                  shallow water flow diverter system of the subsea diverter and rotating drilling head  
11                  of the invention is for providing a controlled system for mud, cuttings and cement  
12                  that are produced during the installation of subsea wellhead conductors and  
13                  isolating the pressure effect created by water depth. The system of the invention  
14                  has provisions to contain and minimize any shallow water flows that may be  
15                  encountered and provides the ability to shut off any undesired aquifer flows.  
16                  Additionally, the system provides the capability of minimizing any flows that are  
17                  the cause of instability in unconsolidated formations.

18                  The invention includes a diverter housing assembly that consists of an  
19                  upper housing that is flanged to a lower latch assembly. The upper housing  
20                  provides a landing shoulder and locking mechanism for a shallow water flow

1           diverter. The locking mechanism consists of a series of dog segments that are  
2           stroked radially inward and engage a profile on the diverter insert. The lock and  
3           unlock functions for the insert are located on the diverter control panel that is  
4           mounted on the diverter housing assembly. An alignment funnel has been  
5           incorporated into the top of the diverter housing assembly to guide the shallow  
6           water flow diverter insert during installation. In addition, the diverter housing  
7           assembly incorporates a choke to channel drilling cuttings and a relief valve that  
8           is designed to vent should an overpressure condition occur within the diverter  
9           housing assembly. Because the diverter housing assembly is flanged to the lower  
10          latch assembly, it can be easily adapted to lower latch assemblies manufactured by  
11          other suppliers.

12           The lower latch assembly consists of a series of locking dogs that mate  
13          with a mandrel profile on the 38" conductor housing. The locking dogs are  
14          hydraulically actuated through an ROV hot stab located on the diverter control  
15          panel. The lower latch assembly also includes an ROV operated mechanical  
16          override to unlatch the locking dogs from the conductor in the event of a hydraulic  
17          failure.

18           The rotating diverter head insert lands and locks into the housing to  
19          provide a dynamic seal on the drill pipe during drilling operations. The sealing  
20          system incorporates two dynamic seals, the stripper rubber seal and the gripper  
21          seal. The stripper rubber seal is a passive elastomer seal that resides on the lower

1 portion of the drilling head insert and forms the primary sealing barrier. The  
2 gripper seal is a hydraulically energized element seal that forms the secondary  
3 sealing barrier on the drill pipe and grips the drill string. Hydraulic pressure from  
4 the diverter control system compresses the gripper seal assembly around the drill  
5 pipe. As the drill pipe turns, the gripper seal transmits torque from the drill string  
6 to the rotating diverter head insert so it will rotate along with the drill pipe.  
7 Heavy-duty bearings are used above and below the gripper seal assembly to  
8 facilitate this rotation. The drilling head insert is run along with the drill pipe using  
9 a running tool.

1           Brief Description of Drawings

2           Figure 1 is a sectional side view of a drilling head constructed in  
3           accordance with the invention.

4           Figure 2 is an enlarged, left sectional side view of an upper portion of the  
5           drilling head of Figure 1.

6           Figure 3 is an enlarged, left sectional side view of a lower portion of the  
7           drilling head of Figure 1.

8           Figure 4 is a sectional side view of a drilling head constructed in  
9           accordance with the invention, shown located on a subsea wellhead, and with a  
10          drill string mandrel spaced below.

11          Figure 5 is an enlarged sectional view of the drilling head of Figure 4, with  
12          the housing not being shown.

13          Figure 6 is sectional side view of the drilling head of Figure 4, shown with  
14          the drill string mandrel in abutment with the drilling head.

15          Figure 7 is sectional side view of the drilling head of Figure 4, shown  
16          during removal from the wellhead.

1           Best Mode for Carrying Out the Invention

2           Referring to Figure 1, a cylindrical drilling head 11 is used in conjunction  
3           with drill pipe (not shown) having a plurality of tool joints. The tool joints are the  
4           threaded connector portions of each section of pipe and have enlarged outer  
5           diameters over the remaining portion of the pipe. Drilling head 11 has a body  
6           assembly 15 with a lower shoulder 12 that lands on an upward facing shoulder 14  
7           in an external housing 13. In one embodiment, body assembly 15 is removably  
8           secured to housing 13 with an annular split ring or locking member 17. Body  
9           assembly 15 may also be secured to housing 13 with a breech lock (not shown).  
10          When a cam member 18 is rotated downward relative to body assembly 15,  
11          locking member 17 is forced radially outward and seats in a groove 19 in housing  
12          13 to lock body assembly 15 from upward movement.

13          Body assembly 15 comprises an outer body 21 having an upper portion  
14          21a and a lower portion 21b which are secured to one another at threads 22.  
15          Body assembly 15 also has a rotor or inner body 23 with an axial bore 25. Inner  
16          body 23 is rotatable relative to stationary outer body 21 on upper bearings 31 and  
17          lower bearings 33. In the preferred embodiment, bearings 31, 33 are tapered  
18          spherical roller bearings.

19          As shown in Figure 2, an annulus 41 extends between outer body 21 and  
20          an upper portion of inner body 23. An inlet port 43 and two outlet ports 45, 47  
21          (Figure 1) communicate hydraulic fluid or lubricant with annulus 41. Seals 44 seal

1 ports 43, 45 between housing 13, cam member 18 and outer body 21. Annulus  
2 41 is sealed on an upper side by seals 46, 52 and on a lower side by seal 49 (Figure  
3 1). Seals 46, 52 and 49 slidingly engage inner body 23 and are each supported by  
4 a seal holder 52a. A bronze bushing 56 is located between each seal holder 52a  
5 and inner body 23. Bushings 56 are provided as sacrificial wear elements to  
6 prevent erosion to seals 46, 52 and 49 and seal holders 52a as rotor body 23 slides  
7 laterally within outer body 21, and to transmit the lateral motion from rotor body  
8 23 to seal holders 52a. In the preferred embodiment (not shown), seals 46, 52 and  
9 49 comprise seals as described in U.S. Patent No. 4,484,753 to Kalsi. Each seal  
10 46, 52 handles one half of the hydraulic fluid pressure at the upper end of drilling  
11 head 11. Seal 46 reduces the pressure by 50 percent, while seal 52 absorbs the  
12 residual pressure to prevent the leakage at the upper end of annulus 41. Seals 46,  
13 52 also have parallel passages 50 that communicate with port 45 for flowing  
14 lubricating fluid through the seal. Seals 46, 52 and 49 also have seals 54 for  
15 preventing drilling mud from contacting bearings 31, 33.

16       Inner body 23 has a centrally located packer or gripping member 51 with  
17 an inner portion 53 and an outer portion 55. Inner portion 53 comprises a solid  
18 annular elastomer 57 that is supported by rigid segments 59. Segments 59 have  
19 radially inward facing, C-shaped cross-sections. Inner portion 53 is free to slide  
20 radially relative to inner body 23. Elastomer 57 defines the smallest inner diameter  
21 of gripping member 51. In an unenergized state, the inner diameter of elastomer

1        57 is greater than the diameter of the drill pipe but slightly smaller than the  
2        diameter of the pipe joints. In an energized state, the inner diameter of elastomer  
3        57 is smaller than the diameter of the drill pipe. The outer diameter of inner  
4        portion 53 abuts the inner diameter of outer portion 55. Outer portion 55  
5        comprises a channel or annular elastomer 61 having a radially outward facing, C-  
6        shaped cross-section and with an annular cavity 63. Elastomer 61 has a pair of  
7        lips 65 that protrude toward one another. Cavity 63 communicates with annulus  
8        41 through a passage 67. Drill head 11 contains an optional labyrinth seal 68  
9        between inner body 23 and outer body upper portion 21a. Labyrinth seal 68 is  
10      provided for limiting or restricting flow of the lubricant toward lower bearings 33.  
11      Because of the close clearance between outer body 21a and inner body 23 and/or  
12      labyrinth seal 68, the lubricant pressure around lower bearings 33 will be less than  
13      that around upper bearings 31. As a result, the lubricant circulating through  
14      annulus 41 exerts a downward force on inner body 23 that will partially offset the  
15      upward force exerted on inner body 23 by well bore fluid.

16      Referring now to Figure 3, a primary seal 71 extends from a lower end of  
17      inner body 23 and is spaced axially apart from gripping member 51. Seal 71 has  
18      a tubular member 72 that threadingly engages an outer portion of inner body 23.  
19      Seal 71 also comprises an elastomer 73 which has a frustoconical exterior and a  
20      tapered metal ring 75 along an inner surface. Ring 75 is slit from a lower end.  
21      Ring 75 has conically-arrayed reinforcement webs 75a that reinforce elastomer 73.

1       The upper end of ring 75 is rigidly fastened to a flange 74 on the lower end of  
2       tubular member 72 with a lock ring 76. The lower end of ring 75 mechanically  
3       engages an inner portion of elastomer 73. Elastomer 73 is molded around flange  
4       74 and ring 75 to give elastomer 73 greater rigidity against inward-directed forces.  
5       The slit in ring 75 allows the individual webs 75a to flex radially outward with  
6       elastomer 73 in a hinge-like fashion. Elastomer 73 has an axial passage with an  
7       upper conical portion 78a, a central cylindrical portion 78b, and a lower conical  
8       portion 78c. The internal diameter of central cylindrical portion 78b is smaller  
9       than the diameter of bore 25, gripping member 51, and the outer diameter of the  
10      drill pipe. Seal 71 provides the primary seal for sealing drilling head 11 against the  
11      drill pipe. Gripping member 51 causes seal 71 to rotate with the drill pipe and  
12      provides an auxiliary or secondary seal for sealing drilling head 11 against the drill  
13      pipe.

14           In operation, a string of drill pipe is lowered through bore 25 of drill head  
15      11 (not shown). Bore 25 is large enough to permit the enlarged diameter of the  
16      tool joints to pass through. When tool joints are lowered through seal 71,  
17      elastomer 73 and ribs 75 flex radially outward as the tool joint passes through seal  
18      71. As the tool joint exits seal 71, seal 71 contracts back to its original shape with  
19      central portion 78b sealing around the drill pipe.

20           During drilling, gripping member 51 is energized to grip and provide a  
21      secondary seal around the drill pipe, thereby causing body 23 to rotate with the

1           drill pipe. This is done by pumping hydraulic fluid through inlet port 43. As the  
2       hydraulic fluid circulates through annulus 41 and out outlet ports 45, 47, bearings  
3       31, 33, upper seal 46 and lower seal 49 are simultaneously lubricated by the  
4       hydraulic fluid. The hydraulic fluid also enters cavity 63 through passage 67. This  
5       pressure energizes gripping member 51 by pressing radially inward against outer  
6       portion 55, which exerts pressure against inner portion 53. Due to labyrinth seal  
7       68, the pressure in the upper portion of annulus 41 is higher than the pressure in  
8       the lower portion of annulus 41. As a result, the upward force applied to inner  
9       body 23 by the well fluid pressure is at least partially counteracted by a downward  
10      force exerted on inner body 23 by the hydraulic fluid.

11           Referring to Figure 4, drilling head 111 is designed to be easily tripped into  
12       and out of engagement with the wellhead during subsea use. Drilling head 111 is  
13       used in conjunction with drill pipe 112. Drilling head 111 has a body 115 that  
14       lands in a tubular diverter housing 113. Body 115 is removably secured to  
15       diverter housing 113 with hydraulically-actuated dogs 117 at an upper end. Dogs  
16       117 are forced radially inward and seat in an external profile on body 115 to lock  
17       drilling head 111 from upward movement.

18           Referring to Figure 5, body 115 is formed of several components,  
19       including an outer body 121 and an inner body 123. Inner body 123 is located  
20       within outer body 121 and has an axial bore 125. Inner body 123 is rotatable  
21       relative to inner body 121 on bearings 131, 133. An annular hydraulic fluid

1 reservoir 141 is located between two portions of outer body 121. An inlet port  
2 143 leading from an exterior fluid supply is used to fill annulus 141 with hydraulic  
3 fluid. Fluid is circulated from annulus 141 through outlet ports 156, through  
4 spaces between inner body 123 and outer body 121, and through bearings 131,  
5 133. Upper and lower circulation ports 144 return fluid back to annulus 141. The  
6 circulation is caused by upper and lower helical vanes 158, 160. Upper helical  
7 vane 158 extends in one direction and is mounted to the exterior sidewall of inner  
8 body 123 for rotation therewith. Lower helical vane 160 is mounted to the  
9 exterior of inner body 123 and extends in the opposite direction. Vanes 158 and  
10 160 join each other at outlet ports 156. As shown by the arrows, rotation of inner  
11 body 123 causes fluid to circulate upward through bearings 131 and downward  
12 through bearings 133. The fluid returns to annulus 141 through circulation ports  
13 144. Fins 162 may be located on the exterior of outer body 121 for enhanced  
14 cooling.

15 Drilling head 111 utilizes a number of seals to seal between these  
16 components. Inner body 123 has a centrally located packer or gripping member  
17 151 which when engaged, grips drill pipe 12. Referring to Figure 4, drilling head  
18 111 also has a primary seal 171 on a lower end. Seal 171 has a reinforced  
19 elastomer 173. Elastomer 173 has an axial passage with a diameter which is  
20 smaller than the outer diameter of drill pipe 112. Seal 171 provides the primary  
21 seal for sealing drilling head 111 against drill pipe 112. Gripping member 151

1 causes seal 171 to rotate with the drill pipe and provides an auxiliary or secondary  
2 seal for sealing drilling head 111 against drill pipe 112.

3 Primary seal 171 is located concentrically within a cylindrical cavity 175  
4 located in the lower end of outer body 121. The lower end of elastomer 173  
5 extends slightly below the lower end of outer body 121. A drilling head support  
6 177 is connected into the string of drill pipe 112. Referring to Figure 4, drilling  
7 head support 177 has a tubular body which is open on its upper end. A lower  
8 portion of drilling head support 177 has an axial bore 179 for the passage of fluids.  
9 Drill pipe 112 extends into drilling head support 177 and is secured to passage  
10 179. Cavity 175 of outer housing 121 and drilling head support 177 may contain  
11 a latching mechanism 181, such as a J-slot mechanism, which releasably couples  
12 drilling head 11 to drilling head support 177 during handling at the surface and  
13 during running-in.

14 Diverter housing 113 has a lower end that releasably latches by latch 184  
15 to an upper end of a subsea outer or low pressure wellhead housing 110. Diverter  
16 housing 113 has a central bore 185 into which drilling head 111 lands. Seals 186  
17 on the exterior of outer body 121 sealingly engage bore 185. A guide funnel 188  
18 extends upward from the sea floor and surrounds wellhead 113 and a lower  
19 portion of diverter housing 113. A diverter side outlet 183 extends laterally from  
20 diverter housing 113 and incorporates a choke 187 to control outflow of drilling

1 returns. A relief valve 189 extends from diverter housing 113 and is designed to  
2 vent should an overpressure condition occur within diverter housing 113.

3 In operation, a large diameter conductor pipe will be installed, with  
4 wellhead 110 being at the upper end. Then drill string 112 is lowered from the  
5 drilling vessel through wellhead 110. Drill pipe support 177 will be secured into  
6 drill string 112 a selected distance from the bit. Drilling head 111 will be coupled  
7 to drill pipe support 177 with J-mechanisms 181. As drill string 112 is lowered  
8 further, outer body 121 will land and seal in diverter bore 185. Dogs 117 will be  
9 actuated to lock drilling head 111 to diverter housing 113. Drill string 112 is  
10 manipulated to disengage the J-mechanism 181, uncoupling drill string support  
11 177 from drilling head 111. Drill string 112 is then lowered until the bit is on  
12 bottom and drilling will begin. By supplying hydraulic fluid pressure, gripper 151  
13 is actuated to grip drill string 112, causing inner body 123 to grip drill pipe 112.  
14 As drill string 112 rotates, inner body 123 will rotate relative to outer body 121.  
15 Drilling fluid is pumped down drill string 112 and returns back up through  
16 wellhead housing 110 and into diverter housing 113. Because of seal 173, drilling  
17 fluid will flow out diverter side outlet 183. Choke 187 will create a desired back  
18 pressure in the drilling fluid contained in the annulus surrounding drill string 112.  
19 When tool joints are lowered through seal 171, elastomer 173 flexes  
20 radially outward as the tool joint passes through it. As the tool joint exits seal  
21 171, seal 171 contracts back to its original shape and seals around drill pipe 112.

1 Referring now to Figures 6 and 7, drilling head 111 is designed to be easily  
2 removed from diverter housing 113. This operation is performed by lifting drill  
3 pipe 112 upward. As drill pipe 112 is raised, drilling head support 177 is also  
4 lifted upward toward drilling head 111 until it engages the lower end of drilling  
5 head 111 (Figure 6). Dogs 117 are disengaged from outer housing 121 so that  
6 drilling head 111 can be lifted out of diverter housing 113 along with drill pipe 112  
7 and drilling head support 177 (Figure 6). There is no need to couple J-  
8 mechanisms 181 during retrieval. Drilling head 111 can be reinstalled by reversing  
9 these steps.

10 Once drilling is completed, a retrieval tool will engage diverter housing  
11 113. With latches 184 released, diverter housing 113 will be retrieved. Then a  
12 string of casing will be run along with a high pressure wellhead housing located  
13 on the upper end. The high pressure wellhead housing will land in low pressure  
14 wellhead housing 110. A blowout preventer will be mounted to the high pressure  
15 wellhead housing. Drilling will continue.

16 The invention has numerous advantages. The system allows a positive  
17 pressure to be maintained on the drilling mud. This reduces the tendency for  
18 shallow formation to flow. The drilling head is readily installed and retrieved  
19 remotely.

1           Although the invention has been shown in only one of its forms, it should  
2       be apparent to those skilled in the art that it is not so limited, but is susceptible to  
3       various change without departing from the scope of the invention.

1           In the Claims:

- 2           1. A subsea drilling assembly comprising:  
3                 a housing adapted to be mounted to the wellhead, the housing having a  
4                 bore;  
5                 a drilling head adapted to be lowered from a drilling vessel landed in said  
6                 housing, the drilling head having a rotatable seal that is adapted to sealingly  
7                 engage and rotate with the drill pipe;  
8                 an outlet for said bore of said housing for discharging drilling mud flowing  
9                 upward around said drill pipe.
- 10          2. The subsea drilling assembly according to claim 1 further comprising:  
11                 an alignment funnel on a top of said housing for guiding a flow diverter  
12                 insert during installation.
- 13          3. The subsea drilling assembly according to claim 1 further comprising:  
14                 a drill pipe support adapted to be secured in said drill pipe to lower said  
15                 drilling head into said housing and for releasably securing to a drill pipe support.
- 16          4. The subsea drilling assembly according to claim 1 further comprising:  
17                 a drill pipe support that releasably secures to said drilling head to be  
18                 released after landing; and  
19                 a remotely actuated drill pipe connection on a lower end of said housing  
20                 for connection with said subsea wellhead.

- 1        5. The subsea drilling assembly according to claim 1 further comprising:
  - 2              a choke on said outlet of said housing.
- 3        6. A subsea drilling comprising:
  - 4              a housing adapted to be mounted to the wellhead, the housing having a bore;
  - 5              a drilling head adapted to be lowered from a drilling vessel landed in said housing, the drilling head having a rotatable seal that is adapted to sealingly engage and rotate with a drill pipe;
  - 6              a drill pipe support adapted to be secured in said drill pipe to lower said drilling head into said housing and for releasably securing said drilling head to a drill pipe support; and
  - 7              an outlet for said bore of said housing for discharging drilling mud flowing upward around said drill pipe.
- 14       7. The subsea drilling assembly according to claim 6 wherein said drilling head is releasably secured to said drill pipe support with a J-mechanism.
- 16       8. The subsea drilling assembly according to claim 6 further comprising:
  - 17              a choke on said outlet of said housing.
- 18       9. A method of subsea drilling comprising:
  - 19              mounting a housing to a wellhead installed at a seafloor, the housing having a bore;
  - 21              lowering a drilling head from a drilling vessel landed in the housing;

1 sealingly engaging a drilling pipe with a rotatable seal in said drilling head  
2 and rotating with the drill pipe; and  
3 discharging drilling mud flowing upward around the drill pipe out of an  
4 outlet from the bore of the housing.

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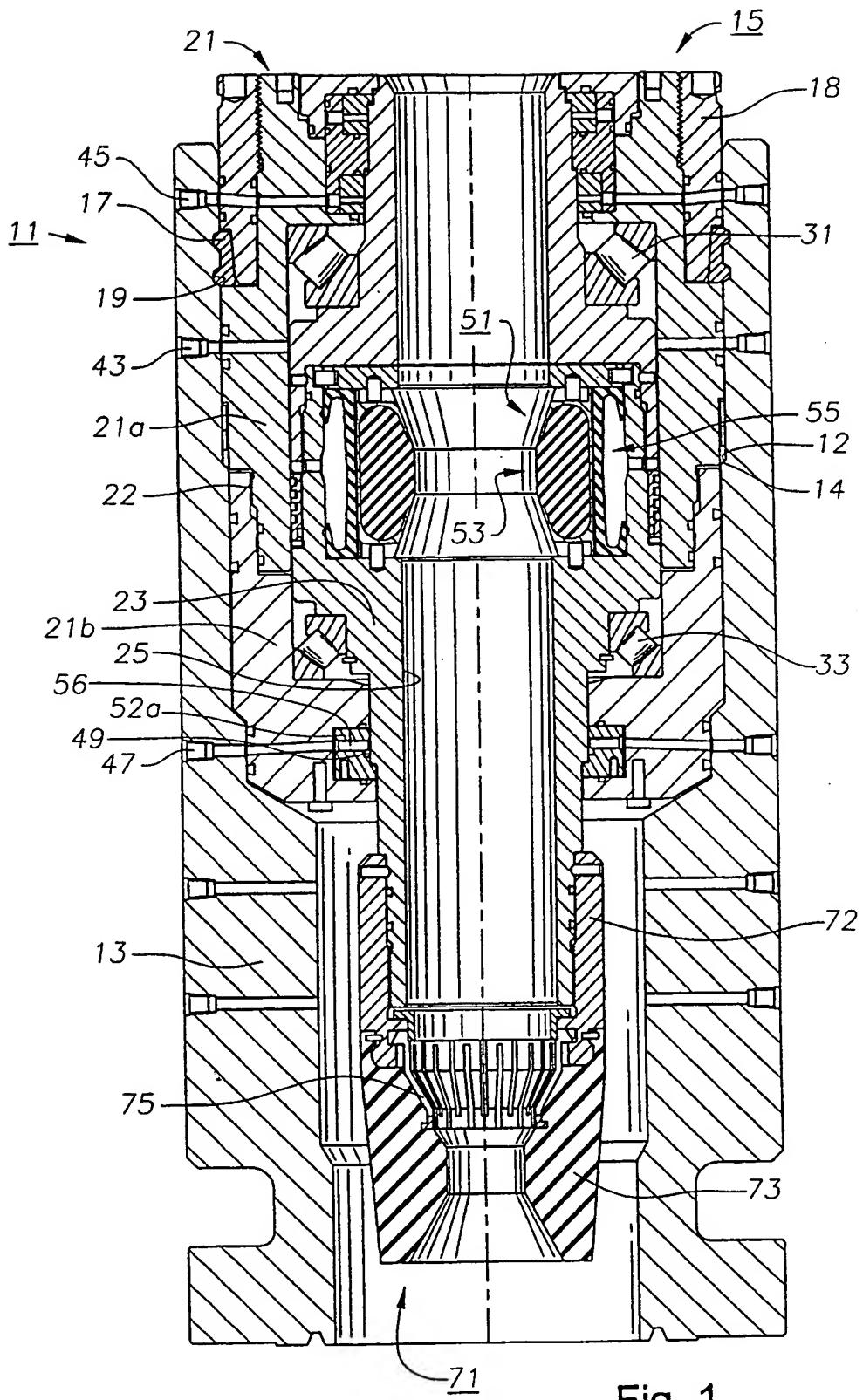


Fig. 1

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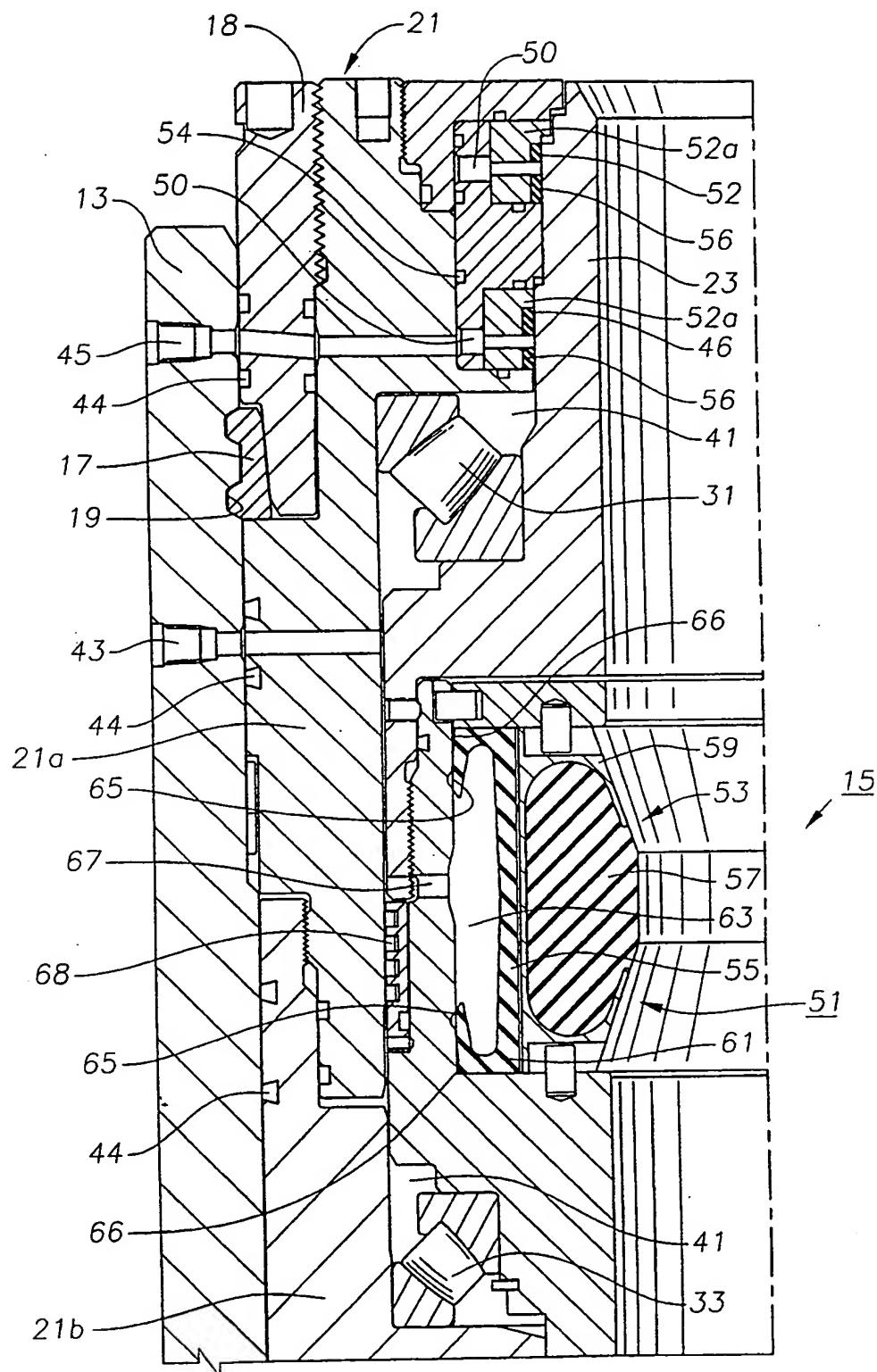


Fig. 2

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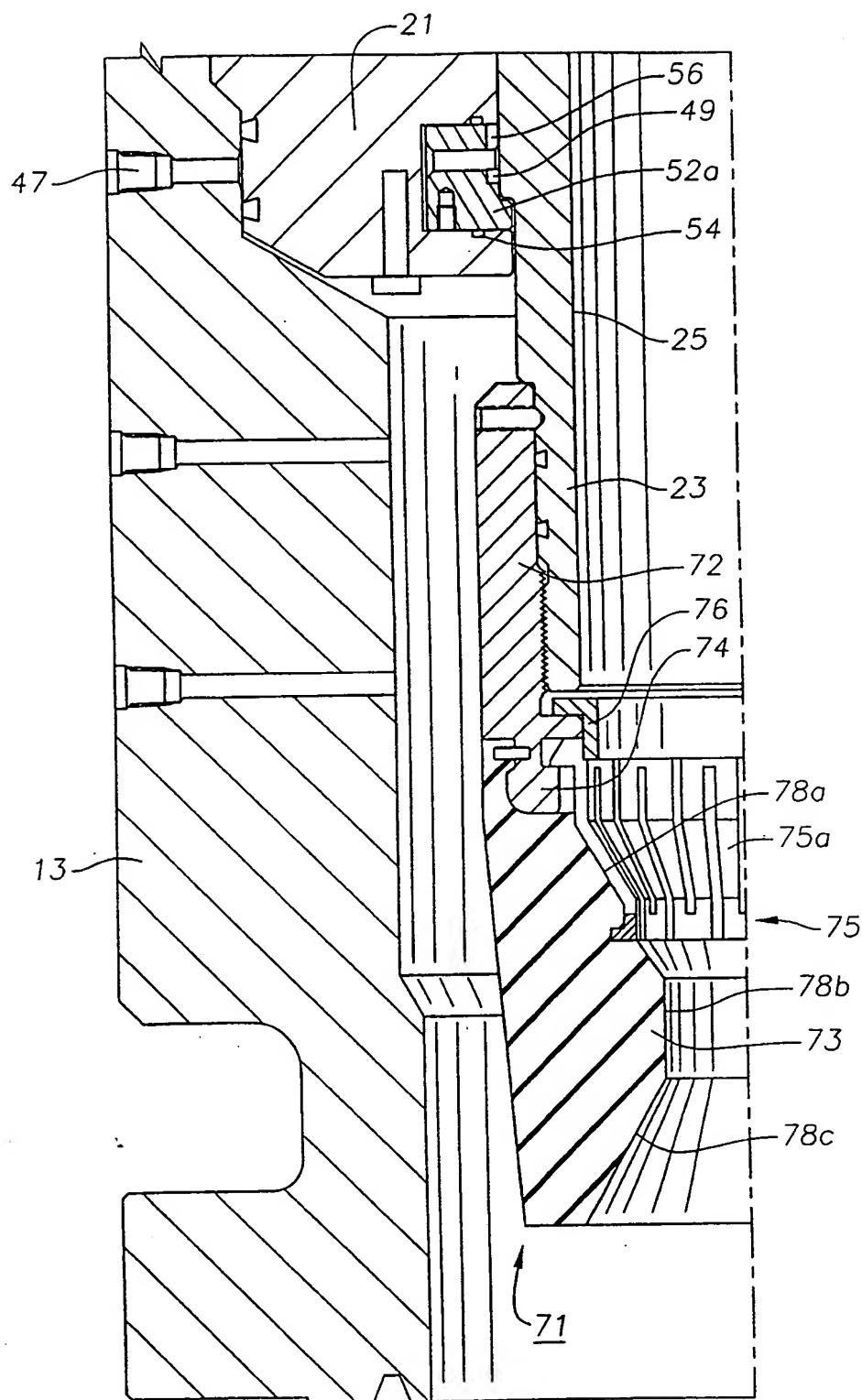


Fig. 3

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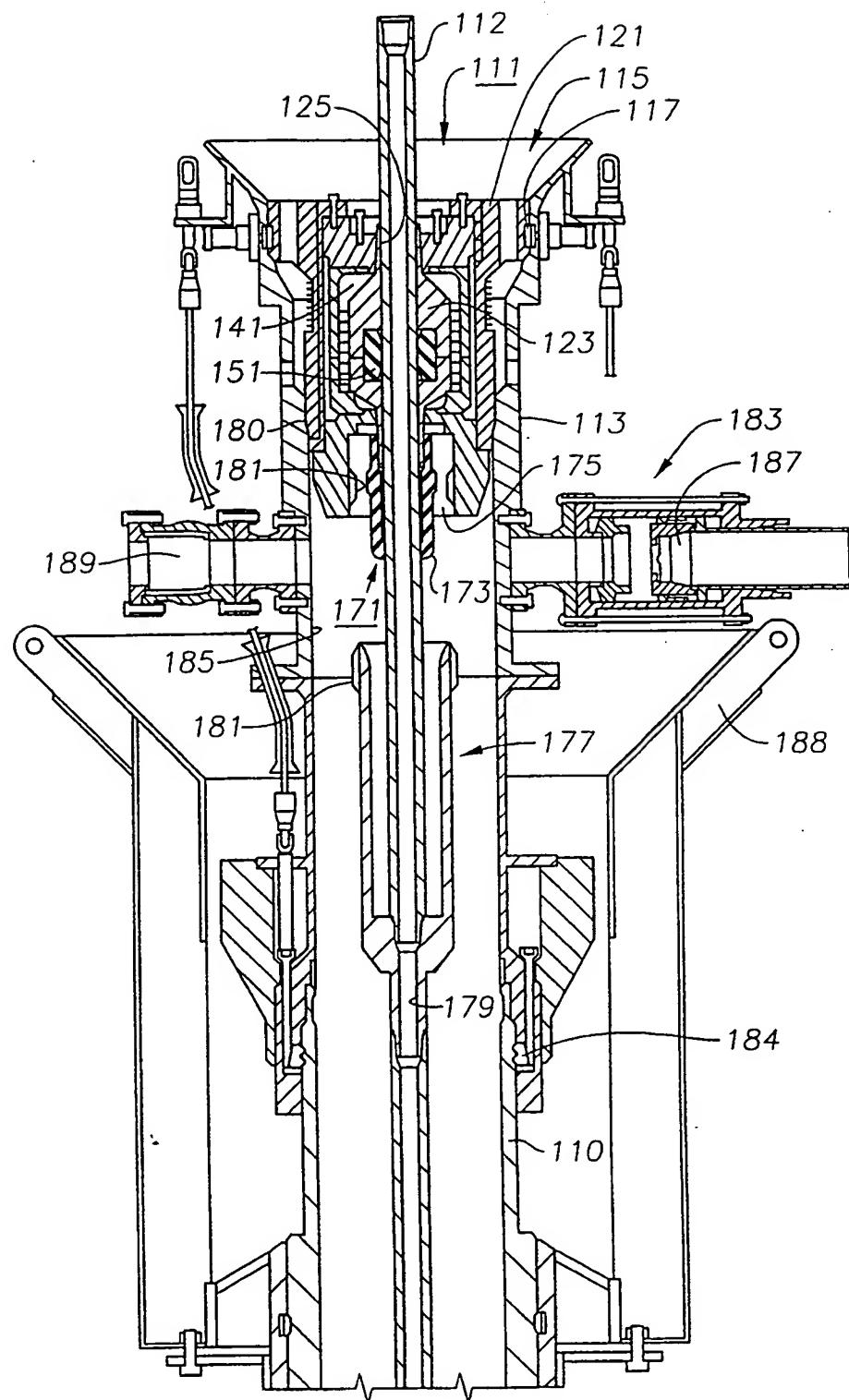


Fig. 4

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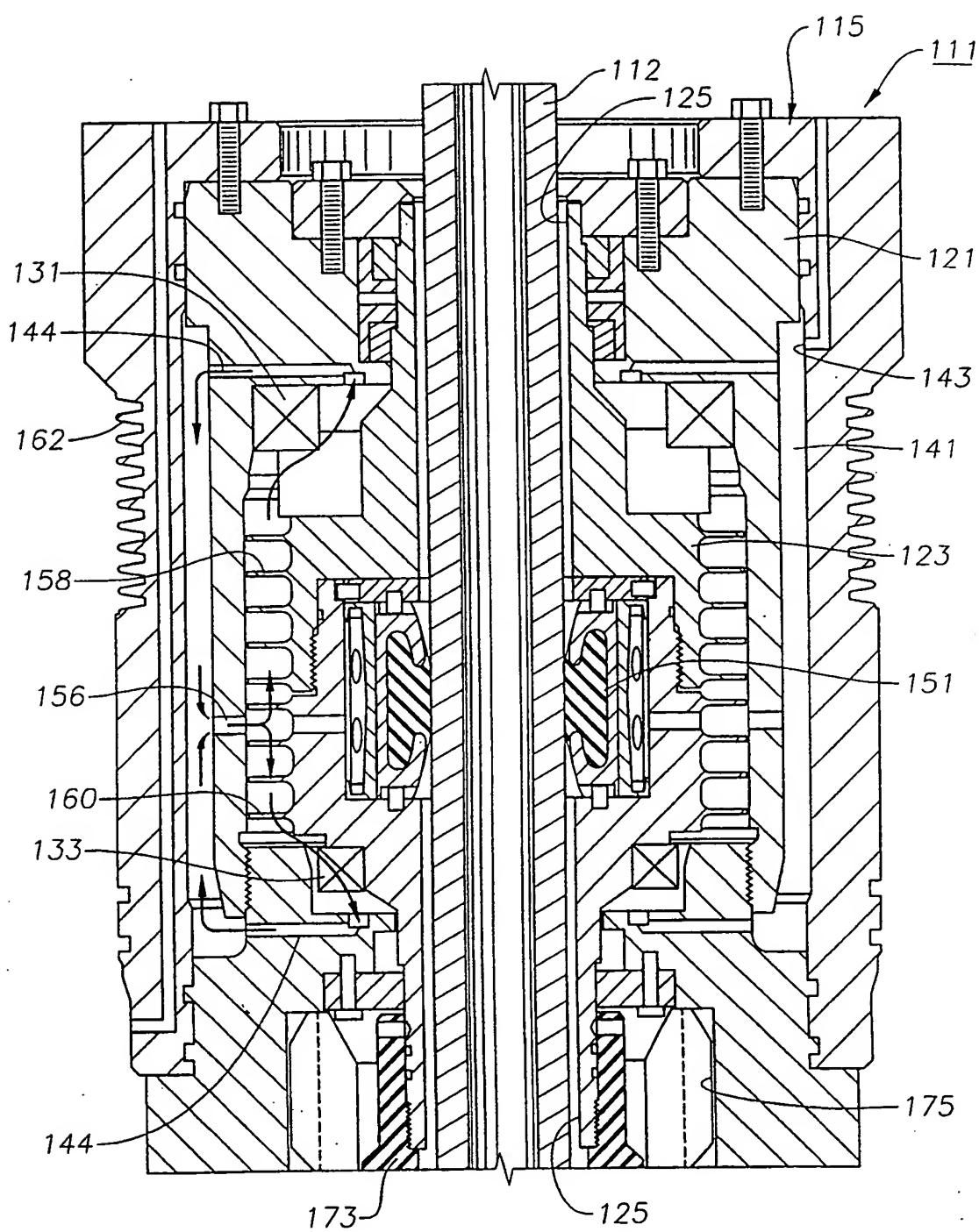
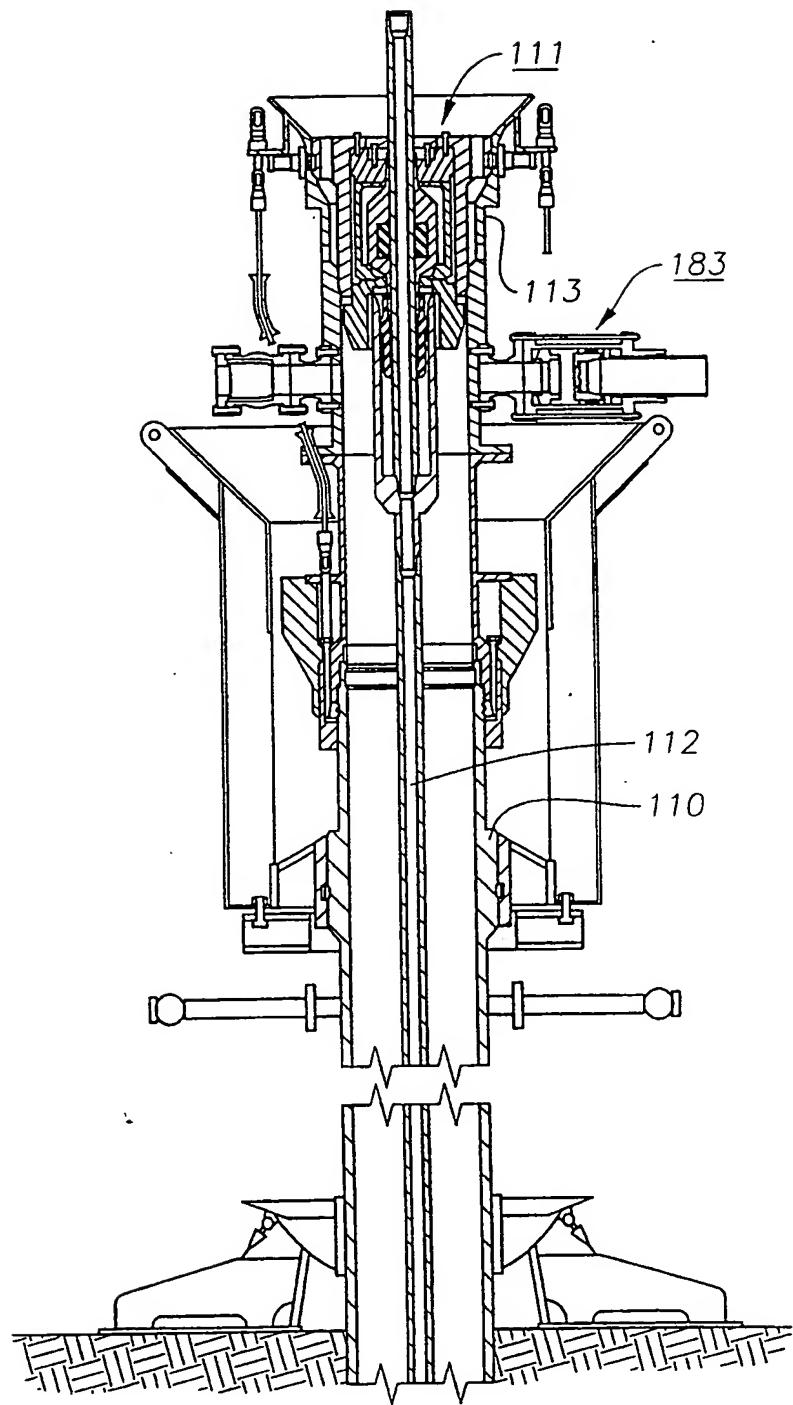


Fig. 5

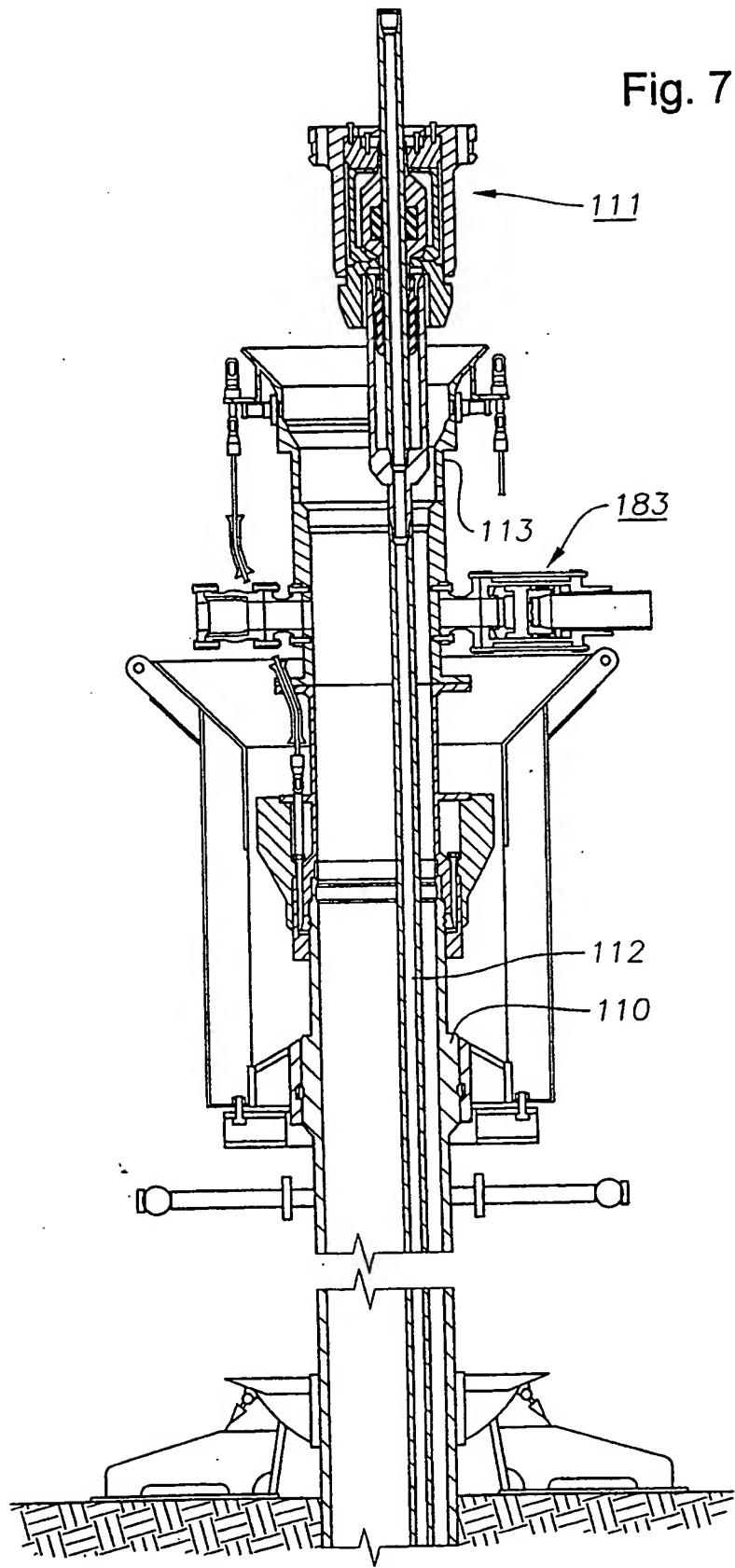
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Fig. 6



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Fig. 7



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 99/07597

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 E21B33/08 E21B21/00 E21B21/08

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 290 250 A (CONOCO INC) 9 November 1988 (1988-11-09) column 4, line 13 - line 21; figures column 4, line 64 - column 5, line 65	1-3, 5, 6, 8, 9
X	US 3 638 721 A (HARRISON OTTO R) 1 February 1972 (1972-02-01) column 2, line 42 - line 69; figures	1, 2, 9

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

30 July 1999

Date of mailing of the International search report

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International Application No

PCT/US 99/07597

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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